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TP 1624

Marine Casualty Investigations

Enquêtes sur les accidents maritimes

Investigation Report to the Minister pursuant to sections 542 or 545 of the Canada Shipping Act

Rapport d'investigation au Ministre conformément aux articles 542 ou 545 de la Loi sur la marine marchande du Canada

Canada

Ce rapport est aussi disponible en français.

REPORT OF INVESTIGATION INTO THE CIRCUMSTANCES ATTENDING THE FLOODING OF DOUBLE-BOTTOM BALLAST TANKS IN THE LIBERIAN FLAG OBO VESSEL "DODSLAND", WHILE EN ROUTE TO QUEBEC, CANADA, FEBRUARY 17, 1987.

REPORT No 483

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REPORT OF INVESTIGATION INTO THE CIRCUMSTANCES ATTENDING THE FLOODING OF DOUBLE-BOTTOM BALLAST TANKS IN THE LIBERIAN FLAG OBO VESSEL "DODSLAND", WHILE EN ROUTE TO QUEBEC, CANADA, FEBRUARY 17, 1987.

Particulars of Vessel

Name	"DODSLAND"
Official Number	7697
Port of Registry	Monrovia
Flag	Liberia
Gross Tonnage	45,278
Net Tonnage	24,427
Length	243.82 m
Breadth	32.21 m
Depth	19.51 m
Draughts Departure Sullom Voe	12.71 m forward 13.77 m aft 13.24 m mean
Arrival Halifax	13.80 m forward 14.01 m aft 13.90 m mean
Winter Draught	13.73 m mean
Type	Oil and bulk or ore (OBO)
Built	Puerto Real, Cadiz, Spain, 1985.
Propulsion	One, 5 cylinder diesel engine of 11,181 kW driving one controllable-pitch propeller
Service Speed	Approximately 12 knots
Cargo	68,031 tonnes crude oil
Classification Society	American Bureau of Shipping (ABS)
Hull	Steel, ABS ice strengthened

	Class C; strengthened for heavy cargo
Owners	Ultramar Shipping Company Inc. Monrovia, Liberia and New York, U.S.A.
Local Agent	F.K. Warren Ltd. Halifax, Nova Scotia, Canada

Navigating Equipment

Radar 1	Raytheon, ranges 0.5 to 64 miles
Radar 2	Raytheon, ranges 0.5 to 64 miles
Radar 3	Horten, ranges 0.375 miles to 48 miles. ARPA; i.e., automatic radar plotting assistance
Compass	Sperry
Steering	(1) Sperry auto pilot (2) Electric, tiller (3) Hydraulic, wheel
Radio Direction Finder	Furuno
Speed Log	Raytheon DSL-250
Loran C	Navidyne ESZ-7000
Satellite Navigator	Navidyne ESZ-4000
Depth Sounder	Furuno with depth alarm
Course Recorder	Sperry
Decca Navigator	Mark 21
Wind Direction and Speed Indicator	Plath

Communications Equipment

Radio Telegraphy	Sait radio

Satellite Communicator	Sperry
VHF Radiotelephone 1	Siemens, Channels 0-80
VHF Radiotelephone 2	Siemens, Channels 0-80
Weather Map Facsimile Machine	Alden Marine, Fax 4

Loading and Ballasting

Computer	Kockumation, Load Master B.20, of Sweden
Cargo Gauging	Saab, radar type level gauges

Description of Vessel

The "DODSLAND" is an all-steel vessel with engines and accommodation situated aft; she is designed to carry either bulk liquid or dry cargoes in her nine cargo tanks/holds; cofferdams separate each of these cargo compartments. Pipe work used when in the tanker mode runs through a duct keel and the cofferdams, thus leaving the cargo compartments clear of obstructions for use when in the bulk dry-cargo mode. A system for heating liquid cargoes is also situated inside the cofferdams. (See Annex 1)

Ballast tanks consisting of double-bottoms and upper and lower wing tanks are situated throughout the lengths of the holds; the lower wing tanks are common with and considered to be part of the double-bottom ballast tanks which extend from the duct keel to the ship's side. (See Annex 2)

A multipoint loading instrument (computer) provides data for all conditions of loading in order to prevent overstressing of the hull during loading and discharging.

All of the vessel's certificates were valid.

NOTE: 1. All times mentioned in this report are expressed in Atlantic Standard Time (UTC minus 4 hours) unless otherwise stated.

2. A Glossary of abbreviations and terms can be found following the Findings in this report.

Background

During the morning of February 17, 1987, the "DODSLAND", fully loaded with a cargo of crude oil, was approaching the Cabot Strait in latitude 45°48'N, longitude 58°57'W when there was found to be ingress of sea-water to two of her double-bottom ballast tanks.

Permission to enter the Gulf of St. Lawrence was withdrawn by the Eastern Canada Traffic Regulating Zone (Ecareg) and the vessel was diverted to Halifax, Nova Scotia, where her hull plating in way of the double-bottom ballast tanks was observed to be fractured.

There was no injury or pollution as a result of this incident.

Narrative

The "DODSLAND" departed Sullom Voe, Shetland Islands, United Kingdom, at 1643 Co-ordinated Universal Time (UTC), on February 3, 1987, bound for St. Romuald, Quebec, Canada, with a full bulk cargo of 68,031 tonnes of North Sea crude oil, the total of which was destined for St. Romuald. The cargo was contained in her 9 holds/tanks; all ballast tanks were empty.

Severe adverse weather conditions were experienced for most of the North Atlantic crossing with westerly winds ranging between 40 and 60 knots resulting in very rough seas. For a period on February 14, the wind was logged at west-south-west 70 knots which is within the Beaufort scale range of hurricane.

The normal passage time for the "DODSLAND" from Suttom Voe to Nova Scotia at her service speed of 12 knots would have been 9 days; however, the adverse weather conditions and frequent reductions in engine speed necessary to alleviate the effects of the weather, increased the passage time to 14 days. During the worst period of the voyage, noon February 14 to noon February 15, the average speed was reduced to 4.42 knots.

A daily, morning routine of sounding all ballast tanks could not be maintained because the severity of the weather prevented access to the sounding pipes which were situated on the exposed deck. As soundings of the double-bottom ballast tanks had not been taken since February 6, the vessel was turned to head easterly during the afternoon of February 14 and soundings were taken during the relatively easier motion

of the ship afforded by the wind and seas being astern. The tanks were found to be empty and a westerly course was resumed some 1.5 hours later. Continuing adverse weather conditions prevented further soundings until the morning of February 17.

During February 15, sea-water ballast amounting to 2,240 tonnes was taken into the fore and aft peak ballast tanks to increase the ship's draught by approximately 30 cm for anticipated ice navigation; the mean draught was then approximately 13.4 metres.

Before entering Cabot Strait, the ship called at Chedabucto Bay, Nova Scotia, and obtained the services of a pilot for advice whilst transitting ice in a non-compulsory pilotage area.

The pilot boarded at 0100, February 17, and the ship then proceeded toward the entrance to Cabot Strait, staying to seaward of concentrations of coastal sea-ice. Some strips of light ice were encountered when off the south-east coast of Cape Breton Island and at 0730, in approximate position 45°43'N, 59°05'W, the ship encountered first-year ice of approximately 20 cm thickness, consisting of small pans of seven-tenths sea coverage; the ice was openly spread and did not affect the ship's speed of 12 knots. The weather by that time had moderated to: wind west-north-west 20 knots, slight sea and unlimited visibility.

At 0830, February 17, one hour after entering ice, soundings revealed that numbers 3 port and 4 starboard ballast tanks were flooded; the water in the sounding pipes was at the level of the sea and each tank contained 1,847 tonnes of sea water.

Both of the ship's main ballast pumps were utilized to discharge both tanks which reduced the water in each to approximately 250 tonnes. The tanks were then allowed to re-flood.

The situation was reported by the vessel to Ecareg and permission for her to enter the Gulf of St. Lawrence (where there were heavy concentrations of pack ice) was withdrawn by Ecareg; however, calculations of bending moments and sheer forces provided by the ship's multipoint loading instrument (computer) in response to data that the two ballast tanks had each been loaded with 1,847 tonnes, indicated that stresses placed upon the hull were still within acceptable limits and permission was requested for traffic clearance to be reinstated.

Clearance was again refused by Ecareg and the vessel

diverted to Halifax, Nova Scotia, at 1600, February 17.

On arrival off Halifax Harbour at 1700, February 18, inspectors from the Ship Safety branch of the Canadian Coast Guard boarded the vessel and after inspection gave clearance for her to enter the harbour. She entered and anchored at 1928 the same day.

During the following morning, February 19, a commercial diving company inspected the outside of the hull using a submersible video camera which revealed the hull plating in way of both ballast tanks to be cracked. The cracks in both cases extended vertically downward from positions below the sides of the cargo compartments, through the bilge keels and then horizontally through the bottom plating towards the duct keel; each was approximately 7.5 m long and 6 mm wide.

Arrangements were made to trans-ship the cargo to St. Romauld via other tankers and for the "DODSLAND" to undergo further inspection in dry-dock at Halifax. She dry-docked March 17, 1987; repairs to the hull were later made in the dry-dock at an approximate cost of $500,000.

Analysis

1. Brief history of the "DODSLAND"

The ship came into service during December 1985 and was making her thirteenth voyage since that time. Of the 12 previous voyages (all were made carrying crude oil), three had been made to St. Romuald, two during February and March 1986 and one during January 1987. There is no record of previous hull damage due to any cause.

2. Departure from Sullom Voe

The "DODSLAND" departed from Sullom Voe in a standard loaded condition, as she had on previous voyages. All cargo compartments were filled to 97% capacity (providing little free surface) and the on-board multipoint loading instrument showed that stresses imposed upon the hull by the cargo and stores were within the acceptable limits of plus or minus 100% for sea conditions. The maximum shear force was -53% and the maximum bending moment -62%. The vessel was trimmed 1.06 m by the stern and slightly sagged.

3. Planned passage

A route was chosen which would take the ship south-

westerly from Sullom Voe to position 42°50'N, 40°00'W and then westerly to position 42°50'N, 50°00'W off the southern edge of the 'tail of the bank' of the 'Grand Bank of Newfoundland'; from there a course north-westerly would take the ship to Chedabucto Bay. This southerly route was chosen in order to avoid extremes of weather which could be expected if the more direct great-circle or rhumb line track had been used.

The route was plotted on British Admiralty Chart number 4011 entitled North Atlantic Ocean; it is reproduced on a map of the North Atlantic contained in the annexes to this report.

4. Weather

South-westerly, westerly and north-westerly winds of 40 to 50 knots were experienced on 11 of the 14 days passage. There were frequent deck log-book notations such as 'vessel rolling and pitching heavily, various courses in order to minimize vessel labouring, heavy seas breaking on deck'.

For three hours during the morning of February 14, the wind was recorded as being south-west force 12 Beaufort scale; i.e., 64 to 71 knots, gusting at times to 70 knots.

The sea state for most of the voyage was as described in the Beaufort scale for a fully arisen sea in winds of force 10 (48 to 55 knots); i.e.:

> Very high waves with long overhanging crests. The resulting foam is in great patches and is blown in dense white streaks along the direction of the wind. On the whole, the surface of the sea takes a white appearance. The rolling of the sea becomes heavy and shock-like. Visibility is affected.

The waves were estimated for most of the voyage to have been between 10 and 12 m high from trough to crest.

5. Ballast-tank soundings

There are two methods of taking ballast-tank soundings. One is by hand using a sounding tape, the other is by a tank gauge system operated by compressed air which allows the content of each tank to be read off gauges in the cargo/ballast control room.

It is the ship's usual practice to hand sound the tanks on a daily basis while at sea and to use the gauge system when ballasting the ship for departure after each cargo discharge.

Due to the severity of the weather and the tank sounding pipes being situated on the exposed weather deck, the routine of hand sounding had not been implemented since February 6, three days after departure from Sullom Voe. The gauge system was not put to use for fear that moisture droplets in the compressed air system, once it was activated, might freeze, rendering the system inoperable when required after discharge of cargo at St. Romauld.

During February 14, which was 8 days after the last set of soundings, the ship was turned from her course of 270° true to head 095° true. This manoeuvre placed the wind and seas astern thereby easing the motion of the ship and ensuring that the now following seas did not break on deck thus allowing access to the sounding pipes.

The course alteration was made at 1325 and after 1 hour, 35 minutes, at 1500, the westerly course of 270° true was resumed. Hand sounding of all ballast tanks had shown them to be empty. No further soundings were taken until February 17 when fine weather was encountered; the weather during February 15 and 16 had continued to be severe westerly with winds of 56 to 63 knots, gradually diminishing to 28 to 33 knots.

6. Ballasting, February 15

During February 15, sea water ballast was loaded in order to increase the ship's draught by approximately 30 cm and give a greater draught for anticipated navigation in ice. Her mean draught would then have been approximately 13.4 metres. The ballast was disposed as follows:

Steering compartment ballast tanks (aft)	510 tonnes
After peak ballast tank	729 tonnes
Forepeak ballast tank	1,001 tonnes
	2,240 tonnes

The disposition of almost equal weights at the extremities of the vessel would also serve to reduce the vessel's slightly sagged condition; no ballast was loaded into the double-bottom tanks and they were presumed still empty.

A stress computation for the new ballast and load condition was not made as the amount of ballast loaded was not considered sufficient to significantly affect the hull-stress safety margins.

7. **Ecareg - Initial report by vessel**

The Ecareg system is a service designed to assist in the safe and expeditious passage of vessels within its area. The vessel complied with Ecareg and sent an initial report February 13 giving her ETA at Chedabucto Bay pilotage station (which is within the Eastern Canada Traffic Zone) together with other required information. This included advice that there were no defects in the ship's hull nor damage sustained (the ballast tank sounding taken on the following day confirmed this information), therefore, traffic clearance to enter the zone was given to the ship in response to her initial message.

8. **Ice conditions in the Gulf of St. Lawrence**

The ice analysis charts issued by Environmental Canada's Ice Forecasting Central, Ottawa and received by the "DODSLAND" via her weather chart facsimile machine, showed that first-year ice was prevalent in the Gulf of St. Lawrence with extensive packs of over nine-tenths coverage of big and giant floes, average thickness 30 centimetres.

9. **Flooded double-bottom tanks**

During the morning of February 17, the usual daily routine of hand sounding tanks was re-established and at 0830, numbers 3 port and 4 starboard were found to be flooded. The water in the sounding pipes was at the same level as the ship's draught; the total capacity of each tank is 1,847 tonnes of sea water.

The ship's two main ballast pumps of capacity 2,500 tonnes per hour (TPH) were used to discharge both tanks which reduced the quantity in each to approximately 250 tonnes. The tanks were then allowed to re-flood and it was calculated that ingress of sea water was as follows:

Number 3 port	600 TPH
Number 4 starboard	400 TPH

There was no change in the quantity of cargo as indicated by the cargo gauges, nor was any oil leakage to

the sea observed.

10. Subsequent reports to Ecareg

At 1342, February 17, a message to Ecareg advised them of the situation, that the ballast pumps could control the flooding and requested confirmation that traffic clearance was still valid.

At 1413, Ecareg replied that traffic clearance was no longer valid and permission to enter the Gulf of St. Lawrence was denied; adding that further information would be provided shortly. At 1542, the ship acknowledged withdrawal of traffic clearance but added that, with the two double-bottom tanks full plus her cargo and the ballast loaded on February 15, the on-board multipoint loading instrument showed that stresses were amply within safety margins and requested that traffic clearance be reinstated. The vessel was still proceeding towards the Gulf of St. Lawrence.

At 1600, Ecareg advised the vessel to divert to Halifax or Chedabucto Bay and arrange for inspection by her classification society, the inspection to be witnessed by Canadian Coast Guard marine surveyors. Upon receipt of that advice, the vessel turned about and headed for Halifax, Nova Scotia, arriving off the Halifax Zone Limits at 1700 the following day, February 18.

11. Multipoint loading instrument

The design of modern ships, in particular the design and construction of large specialized ships such as the "DODSLAND", is made primarily by the use of computer in order to optimize the ships' scantlings. This has led to a corresponding need for increased accuracy in the disposition of cargo and/or ballast during loading and discharging.

Classification Societies recognize that injudicious loading can overstress a hull and the International Convention on Load Lines 1966, required that sufficient information in an approved form be supplied to the master of every new ship to enable the loading and ballasting to be carried out in such a way as to avoid the creation of unacceptable stresses in the ship's structure.

In most cases, new vessels are provided by the builders with an approved loading manual covering all standard loading conditions under which the cargo/ballast induced

stresses on the hull fall within acceptable limits. On occasion, standard loading conditions cannot be met and additional information is required by the ship's master; this is met by equipping the ship with an approved multipoint loading instrument (computer).

The "DODSLAND" is equipped with such an instrument. When data covering an intended loading has been entered, the computer shows the shear forces and bending moments to be expected at 20 points throughout the length of the hull and whether or not the stresses are acceptable, either for harbour (still water) or sea conditions, during which stresses additional to those induced by a loaded condition can be expected; i.e., motion in a seaway. To be acceptable, these stresses have to fall within 100% plus or minus and are applicable to the intact hull.

On discovery of the flooded tanks, both were entered into the computer as having been ballasted which, together with the ship's previous loaded and ballasted condition, showed the stresses to be within safety margins for sea conditions. The maximum shear force was -65%, the maximum bending moment -60%; permission to enter the Gulf of St. Lawrence was requested by the ship on that basis plus the fact that the ballast pumps were capable of containing the ingress. However, traffic clearance was again denied by Ecareg.

It should be noted that the ship's hull was no longer intact and therefore might not have been able to withstand the above stresses, particularly with additional stresses which would have been incurred through navigating in pack ice.

12. **Time of Damage**

The flooded tanks were discovered at 0830 February 17. The ship had entered loose pack ice at 0730 the same day; the maximum rate of ingress was to number 3 port tank and was calculated at 600 tonnes per hour; therefore, the damage to that tank must have occurred at least three hours before 0830 in order for it to have filled to its capacity of 1,843 tonnes, which was at least two hours before entering ice.

The previous sounding of all tanks had been made between 1325 and 1500, February 14, when they were shown to be empty. Therefore, the damage must have occurred at a time between 1500 February 14 and 0530 February 17.

13. Investigation into the hull fractures

The Marine Casualty Investigations Division's Naval Architectural expertise was fully committed to other, urgent, investigations at the time of this incident. However the Ship Safety Branch of the Canadian Coast Guard, the owners and the Classification Society also required a comprehensive analysis to ascertain the reasons for the hull cracking. This led to the P & I club commissioning the Nova Scotia Research Foundation Corporation to carry out the necessary metallurgical investigation. The 'Discussion' and 'Conclusions' sections of the Corporation's report are attached as Annex 3.

The report covers, in detail, the complexities involved but in essence, the cause of the hull plating failure was attributed to the formation of fatigue cracks in fillet welds due to poor welding, stress concentration, and the flexing of the hull in service causing cyclical stress on the tips of the intercostal bilge plating stiffeners. The fatigue cracks extended into the shell plating and developed into brittle fractures.

14. Crew Qualifications and Experience

The master holds both Liberian and Italian Master Foreign Going Certificates and had been seafaring for 25 years, the last 10 of which as master; he had held command of the "DODSLAND" for 3.5 months and previous command of similar ships for 6 months.

The third officer holds both Liberian and Italian Third-mate Foreign Going Certificates and had been seafaring for 5 years, the last 3.5 months on the "DODSLAND".

The pilot holds a British Master Foreign Going Certificate and an APA pilotage licence. He had been seafaring for 30 years including pilotage for the past 12 years.

Findings

The 15 month old, Liberian registered, OBO vessel "DODSLAND" sustained cracks in her bottom and lower hull shell plating in way of two of her double bottom tanks while crossing the Atlantic Ocean en route to Quebec, Canada, loaded with a full cargo of crude oil. The cause of the cracking is complex but, in simple terms it would appear that:

- four fatigue cracks, in the shell plating, two on each side of the hull, which commenced as a result of the combined effects of:
  - poor fillet welding, and
  - stress concentration at the tips of stiffeners under service loading.
- the fatigue cracks then developed into serious brittle fractures as a result of:
  - the loaded hull flexing in the seaway;
  - the stress concentration in way of the fatigue crack affected areas;
  - quality of the steel at the low temperatures, and
  - the inability of the adjacent shell plating butt welds to arrest the progress of or divert the brittle fractures.

Other Findings

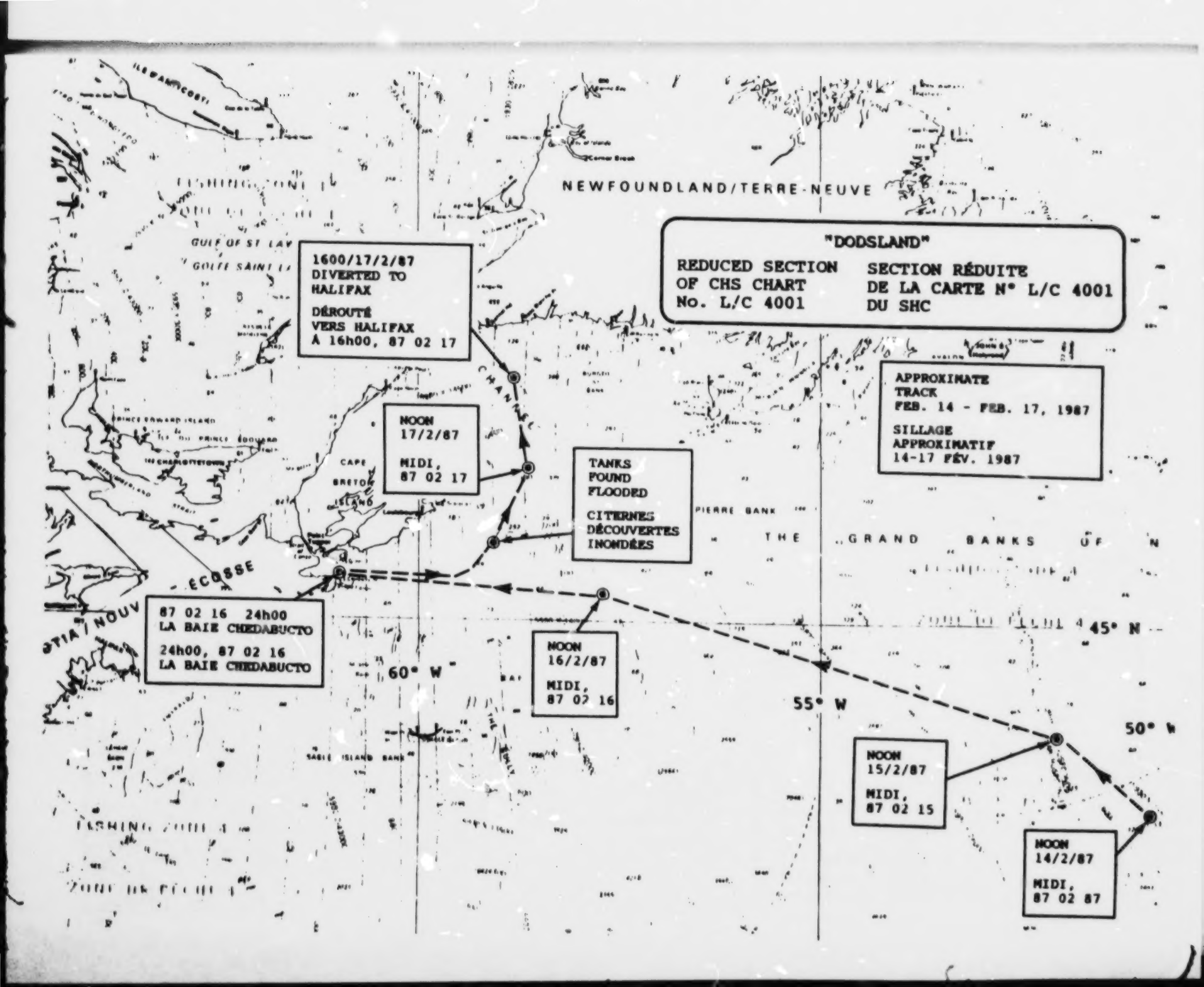
With the knowledge that the vessel's hull was probably breached, continued reliance on the on-board multipoint stress calculations instrument to assess the structural safety was injudicious.

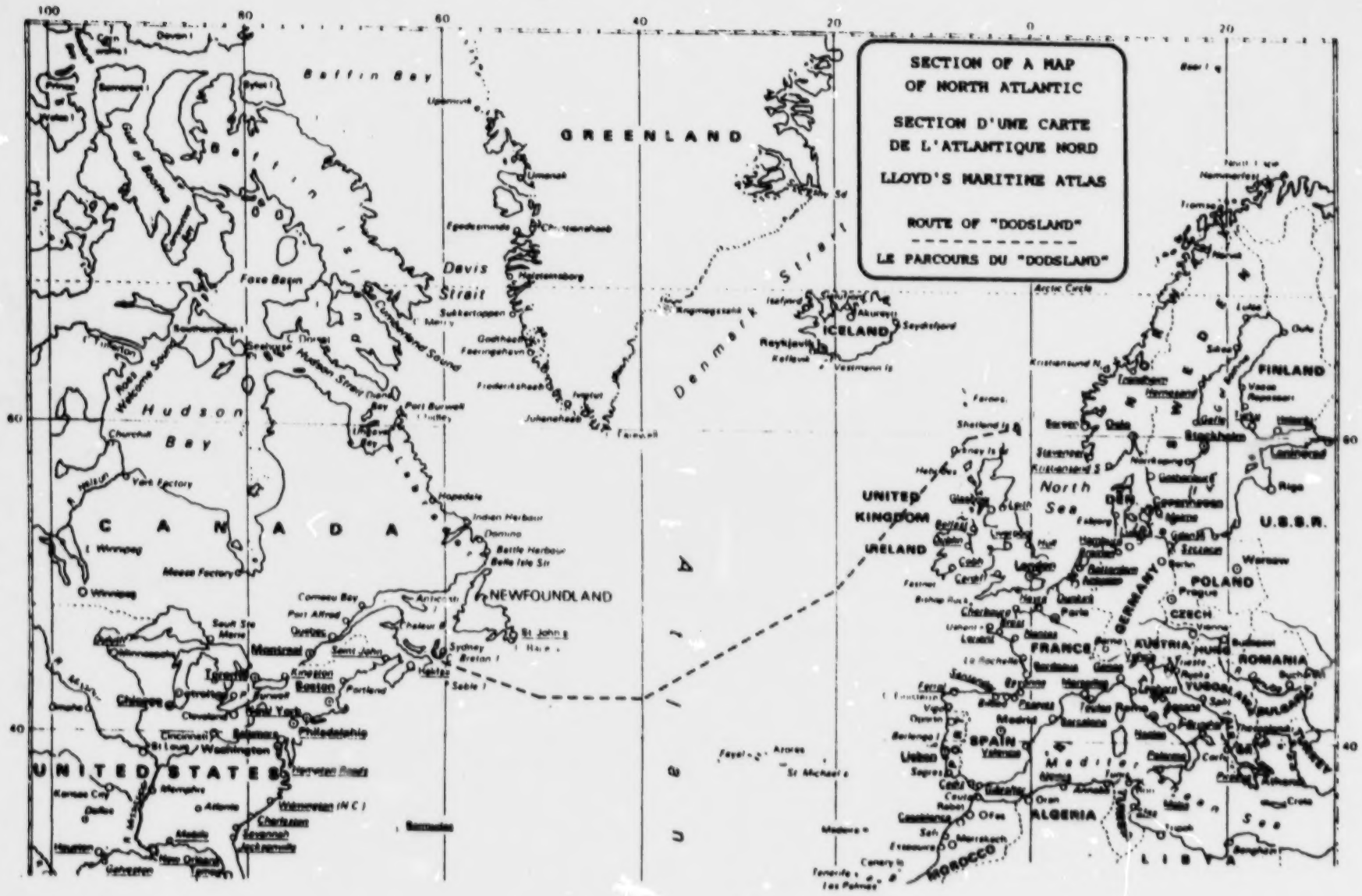
The Ecareg system prudently denied the vessel permission to enter ice congested waters thereby possibly preventing further damage to the vessel and subsequent environmental contamination.

OTTAWA, ONTARIO
AUGUST 1987.

Glossary

Bilge keel	A fin fitted to the hull on each side of ship at the turn of the bilge to reduce rolling.
Cofferdam	The space between two bulkheads separating two adjacent compartments.
Duct keel	A keel built of steel plates and angles in box form extending from the engine-room forward.
Free surface	The area of a body of liquid in a compartment free to remain parallel to the horizontal as a ship rolls and pitches; it has a deleterious effect on stability.
Great circle	The shortest route between two points on a sphere.
Knot	Unit of speed; i.e., 70 knots equals 70 nautical miles per hour or 80.6 statute miles per hour.
Rhumb line track	A curve on the earth's surface which cuts all meridians at the same angle; i.e., a track which maintains the same course to destination.
Sagged	Longitudinally deformed under stress where the middle of a ship's hull bends below its extremities.
Soundings (Internal)	Measuring the depth of a liquid inside a tank or compartment in order to determine quantity.
UTC	Co-ordinated Universal Time.


"DODSLAND"
REDUCED SECTION OF CHS CHART No. L/C 4001
SECTION RÉDUITE DE LA CARTE N° L/C 4001 DU SHC
1600/17/2/87
DIVERTED TO HALIFAX
DÉROUTÉ VERS HALIFAX
A 16h00, 87 02 17
APPROXIMATE TRACK
FEB. 14 - FEB. 17, 1987
SILLAGE APPROXIMATIF
14-17 FÉV. 1987
NOON 17/2/87
MIDI, 87 02 17
TANKS FOUND FLOODED
CITERNES DÉCOUVERTES INONDÉES
87 02 16 24h00
LA BAIE CHEDABUCTO
24h00, 87 02 16
LA BAIE CHEDABUCTO
NOON 16/2/87
MIDI, 87 02 16
NOON 15/2/87
MIDI, 87 02 15
NOON 14/2/87
MIDI, 87 02 87
NEWFOUNDLAND/TERRE-NEUVE
PRINCE EDWARD ISLAND
CAPE BRETON ISLAND
PIERRE BANK
THE GRAND BANKS OF N
SABLE ISLAND BANK
45° N
60° W
55° W
50° W


SECTION OF A MAP
OF NORTH ATLANTIC
SECTION D'UNE CARTE
DE L'ATLANTIQUE NORD
LLOYD'S MARITIME ATLAS
ROUTE OF "DODSLAND"
LE PARCOURS DU "DODSLAND"
Baffin Bay
GREENLAND
Davis Strait
Denmark Strait
ICELAND
Hudson Bay
CANADA
NEWFOUNDLAND
UNITED STATES
North Sea
UNITED KINGDOM
IRELAND
FRANCE
SPAIN
GERMANY
POLAND
CZECH
AUSTRIA
HUNG.
ROMANIA
YUGOSL.
BULGARIA
U.S.S.R.
FINLAND
ALGERIA
MOROCCO
LIBYA
Mediterranean Sea
Arctic Circle
Montreal
Toronto
Boston
New York
Philadelphia
Chicago
Bermuda
Azores
Madeira
Canary Is
Reykjavik
Thorshavn
Faroes
Shetland Is
Orkney Is
Hebrides
Cape Farewell
Cape Dyer
Resolution I
Southampton I
Coats I
Devon I
Baffin I
Ellesmere I
Prince Patrick I
Victoria I
Banks I
Melville I
Somerset I
Boothia Pen
King William I
Prince of Wales I
Gulf of Boothia
Foxe Basin
Fury and Hecla Strait
Repulse Bay
Southampton I
Coats I
Nottingham I
Wager Bay
Chesterfield Inlet
Baffin I
Cumberland Sound
Frobisher Bay
Hudson Strait
Ungava Bay
Port Burwell
Nain
Hopedale
Indian Harbour
Domino
Battle Harbour
Belle Isle Str
Cormeau Bay
Port Alfred
Quebec
Anticosti I
Sept Iles
Sydney
Cape Breton I
St John's
Halifax
Sable I
Saint John
Portland
Sault Ste Marie
Thunder Bay
Winnipeg
Churchill
Whale R
Nelson R
York Factory
Moose Factory
Severn R
Albany R
Attawapiskat R
Kenora
Duluth
Minneapolis
Chicago
Detroit
Cleveland
Buffalo
Rochester
Albany
Syracuse
Utica
Cincinnati
St Louis
Washington
Baltimore
Harrison Roads
Wilmington (NC)
Charleston
Savannah
Jacksonville
Kansas City
Omaha
Memphis
Atlanta
Dallas
Houston
Galveston
Mobile
New Orleans
Bermuda
Azores
St Michael's
Madeira
Canary Is
Tenerife
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Agadir
Marrakech
Tangier
Malaga
Valencia
Barcelona
Palma
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Nice
Genoa
Naples
Palermo
Corfu
Crete
Tripoli
Benghazi
Bordeaux
La Rochelle
Le Havre
Cherbourg
Brest
Calais
Dunkirk
Antwerp
Rotterdam
Amsterdam
Ijmuiden
Hull
Grimsby
Immingham
Tyne
Leith
Aberdeen
Glasgow
Belfast
Dublin
Cork
Galway
Liverpool
Manchester
London
Felixstowe
Dover
Portsmouth
Plymouth
Falmouth
Bristol
Cardiff
Swansea
Milford Haven
Hamburg
Bremen
Emden
Wilhelmshaven
Kiel
Lubeck
Rostock
Stettin
Gdynia
Danzig
Copenhagen
Aarhus
Esbjerg
Aalborg
Skagen
Oslo
Bergen
Stavanger
Kristiansand S
Kristiansund N
Trondheim
Narvik
Tromso
Hammerfest
Honningsvag
Vardo
Kirkenes
Petsamo
Lulea
Skelleftea
Umea
Sundsvall
Gavle
Stockholm
Norrkoping
Gothenburg
Helsingborg
Malmo
Visby
Riga
Ventspils
Liepaja
Memel
Leningrad
Helsinki
Turku
Vaasa
Oulu
Warsaw
Prague
Vienna
Budapest
Belgrade
Sarajevo
Split
Trieste
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Genoa
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Strasbourg
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Reims
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Gijon
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Sagres
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Tarragona
Alicante
Oran
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Philippeville
Bone
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Tobruk
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Latakia
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Palermo
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Syracuse
Malta
Valletta
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Heraklion
Canea
Suda
Iraklion
Rethymnon
Chania
Kalamata
Volos
Salonika
Kavalla
Dardanelles
Istanbul
Izmir
Antalya
Mersin
Iskenderun
Port Said
Suez
Aden
Bab el Mandeb
Red Sea
Jeddah
Port Sudan
Massawa
Assab
Djibouti
Berbera
Mogadishu
Kismayu
Mombasa
Dar es Salaam
Zanzibar
Beira
Lourenco Marques
Durban
East London
Port Elizabeth
Cape Town
Walvis Bay
Luderitz
Swakopmund
Lobito
Luanda
Matadi
Boma
Pointe Noire
Libreville
Port Gentil
Douala
Victoria
Lagos
Port Harcourt
Calabar
Abidjan
Takoradi
Accra
Tema
Cotonou
Lome
Freetown
Conakry
Monrovia
Dakar
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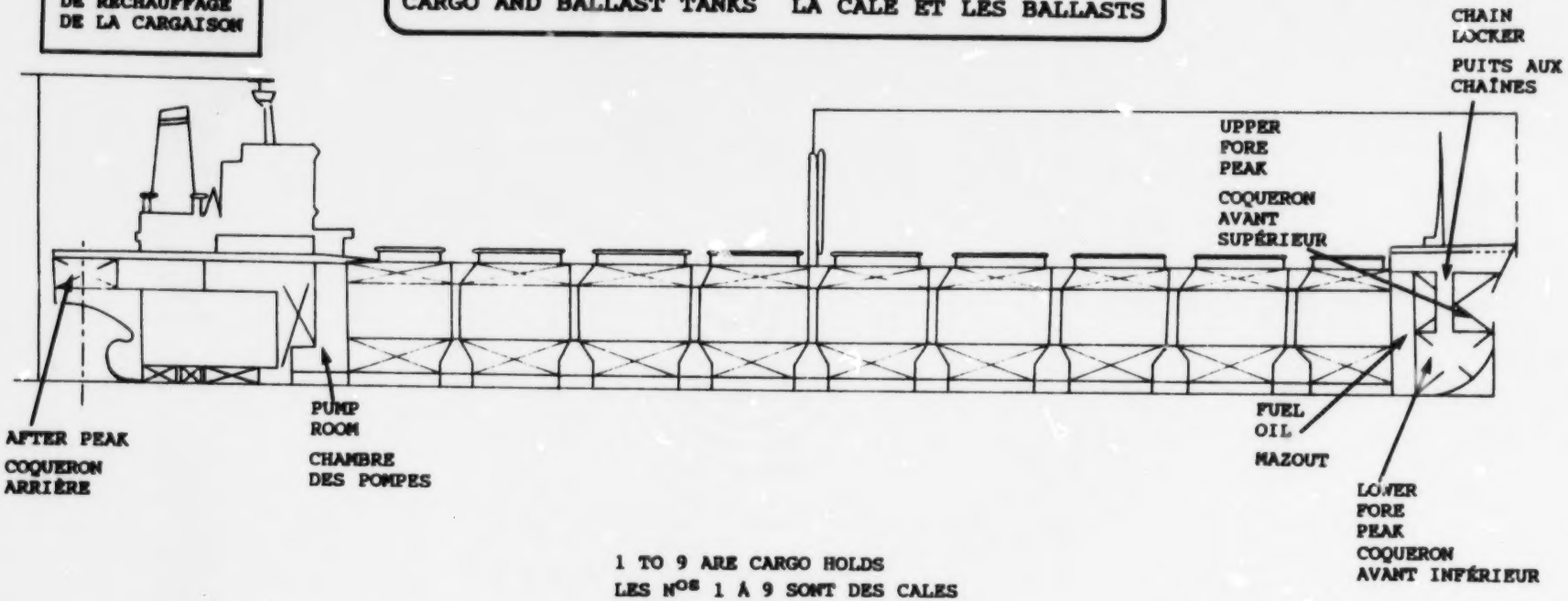
Casamance
Bissau
Las Palmas
Tenerife
Canary Is
Madeira
Azores
St Michael's
Faial
Pico
Sao Miguel
Terceira
Graciosa
Flores
Corvo
Santa Maria
Sao Jorge
Fayal
Horta
Ponta Delgada
Angra
Praia
Mindelo
Sal
Boa Vista
Fogo
Brava
Maio
Santiago
Sao Vicente
Santo Antao
Sao Nicolau
Sao Tiago
Sao Filipe
Praia
Mindelo
Sal
Boa Vista
Fogo
Brava
Maio
Santiago
Sao Vicente
Santo Antao
Sao Nicolau
Sao Tiago
Sao Filipe

ANNEX 1
APPENDICE 1

CARGO HEATING SYSTEM
INSTALLATION DE RÉCHAUFFAGE DE LA CARGAISON

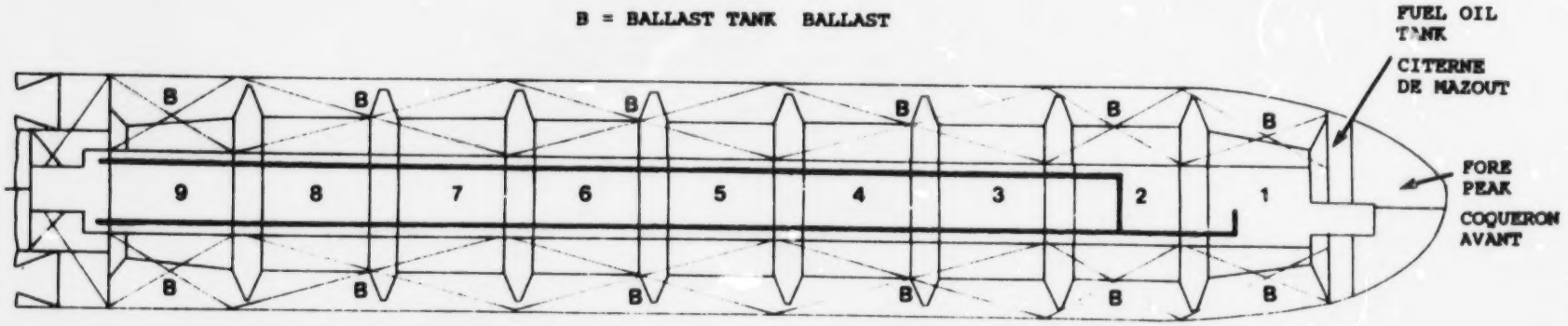
OBO "DODSLAND"
CROSS-SECTION SHOWING CARGO AND BALLAST TANKS

OBO "DODSLAND"
SECTION DÉMONTRANT LA CALE ET LES BALLASTS



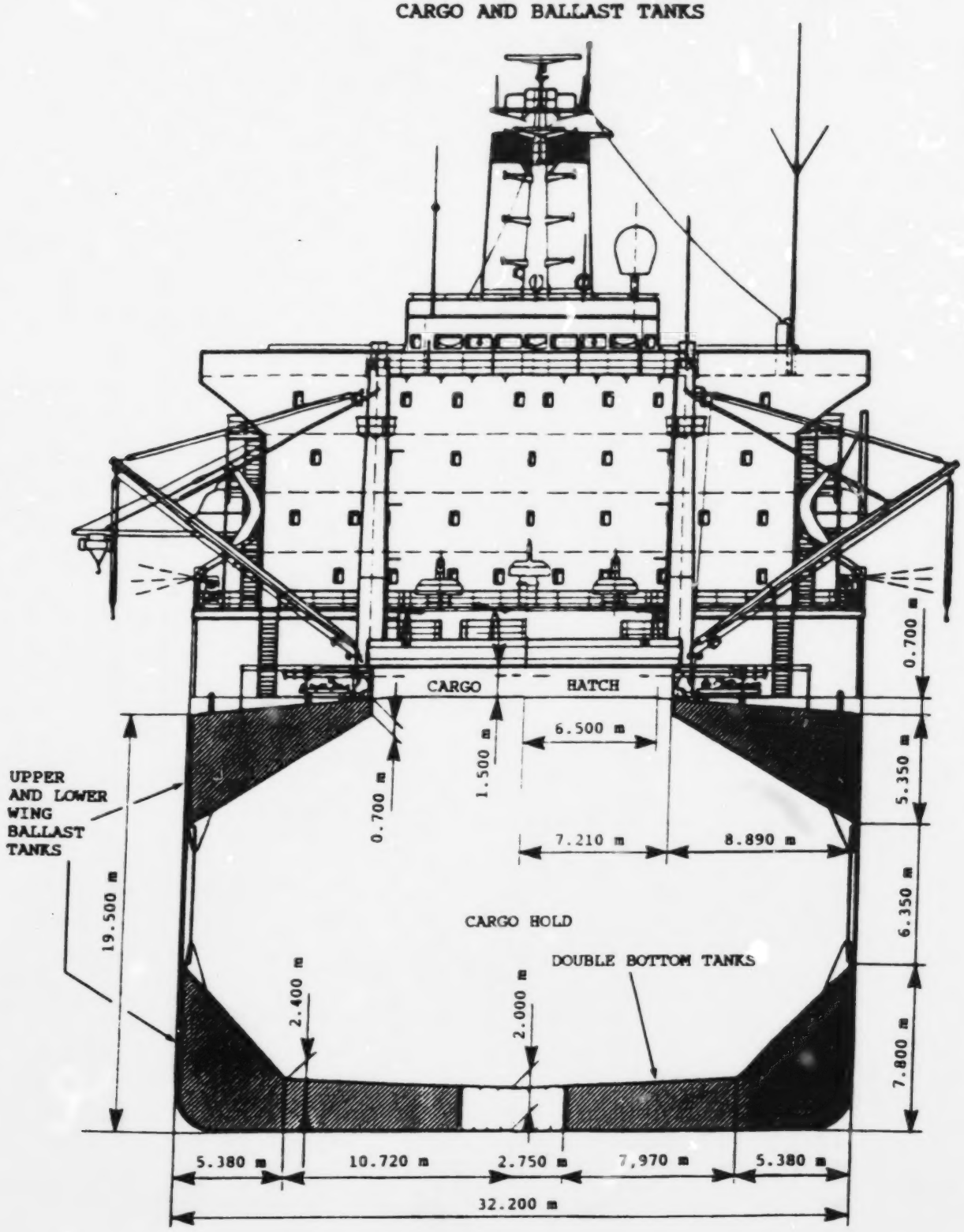
1 TO 9 ARE CARGO HOLDS
LES N^{OS} 1 À 9 SONT DES CALES

B = BALLAST TANK BALLAST



ANNEX 2

OBO "DODSLAND"
CROSS-SECTION SHOWING
CARGO AND BALLAST TANKS



ANNEX 3

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P.O. Box 790
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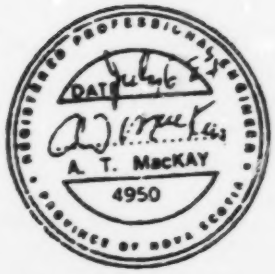
Telex 019-22719

Telecopier (902) 465-7384

INVESTIGATION OF THE HULL PLATE FRACTURE AND CHARACTERIZATION OF THE STEELS ASSOCIATED WITH THE FAILURE OF THE MV DODSLAND NSRFC-HAK-212-86/7



By

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June 1987

9. DISCUSSION

The points of origin of cracks were easily traced from the herringbone directional pattern of the brittle fracture surfaces. In all, four points from where the cracks originated were discovered, two were situated on #4 starboard side and the other two on #3 port side. All four cracks originated near the toes of the fillet welds situated at the tip of the intercostal short stiffeners on the bilge strakes. Beach marks were clearly seen at the fracture origins, indicating fatigue.

Our investigation discovered that the quality of the fillet welds was very poor. The fact that all the cracks originated at the tip of the intercostal stiffeners led us to believe that the tips of these stiffeners, because of poor fillet welds, acted as stress raisers. Under the normal service load, the stress at the tips exceeded the fatigue limit and, consequently, fatigue cracks formed at these points.

Every origin had multiple points of initiation. The length of fatigue cracks at the points of origin were extensive, they were about 3 cm in length along the toes of the fillet welds and penetrated 3 to 5 mm into the shell plate. The growth of the fatigue cracks occurred during the short service life, less than one year, of the MV Dodsland.

When the fatigue cracks reached a critical size, rapid brittle fracture occurred. The combined effects of (1) localized stress concentration at the extensive fatigue cracks, (2) the crucial loading from wave motion and engine vibration, and (3) the insufficient energy absorptive capacity of the shell plate at the service temperature led to brittle fracture.

Our test results indicated that the dynamic tear values of the shell material at the service temperature were low.

The critical crack depth calculated from the COD results gave a value of 6.07 to 7.32 mm (.239 to .288 in.). Although the actual depths of the fatigue cracks before brittle fracture were no greater than 5.0 mm, this discrepancy may be due to the difference in loading between that in the COD tests and actual service. Even though the critical crack depths calculated from the COD test results were slightly higher than the actual depths, they can be considered to be in good agreement.

Our Charpy V-notch tests indicated that the butt welds had slightly higher Charpy impact values compared to the shell plates. However, the brittle cracks passed through most of the butt welds except for the weld between plates #212 and #615 on the starboard side, where

it was arrested. The brittle crack also travelled through the butt weld produced by the submerged arc process between plates #605 and #606. Accidentally, we discovered the presence of weld cracks in one of the Charpy specimens cut from the butt weld between plates #212 and #606 on port side. Considering all the facts, one can state that not only the shell plates, but the butt welds produced by SMAW and submerged arc welding did not have the energy absorptive capacity to resist brittle cracking. The arrest of the cracks in the Dodsland appeared to have occurred when the cracks entered a region of low stress rather than due to entering a region of tougher material.

Our investigation indicated that the transition temperature for the Charpy impact specimens was about 15°C and for dynamic tear specimens, was about 30°C. Below the transition temperatures mentioned above, the shell material under certain loading could lose its fracture toughness or resistance to brittle cracking. In our opinion, for this type of steel in cold water service, the probability of brittle fracture is high.

Our examination of the fracture surfaces by SEM revealed that the fracture mode of the cracks beyond the points of crack arrest were of a shear nature indicating that the service stress at the point of arrest were higher than the yield strength of the plate material.

From the results of chemical analysis and tensile tests, the bilge strake, the side and the bottom strake material can be classified as ABS Grade A Hull Steel. The bilge strake did not meet the requirements for Grade AH.

The measured tensile strength of the bilge strake was slightly higher than that of the side strake. This could be due to the fact that the bilge strake went through an additional forming process for its final curved shape.

The Charpy impact properties, although not required for Grade A plate, were found to have a wide scatter and had a low value at the service temperature. It is generally accepted that materials with anisotropic properties are not suitable for through thickness loading members or joints.

We discovered numerous defects in the fillet welds including cracks, pores, and lack of fusion. In general, the hardness values of the fillet welds and at the fusion line on the shell plate side were relatively higher (than the other welded joints) and appear to coincide with the origin of the cracks. The poor integrity of the fillet welds was one of the causes of the fatigue cracks.

Government bodies and classification societies have given great attention to the selection of materials for offshore structures. To provide protection against brittle fracture, careful selection of materials for ship design should be made to suit its application and service conditions.

10. CONCLUSIONS

The following conclusions were drawn from the results of our investigation.

1. The bilge strake, bottom strake and the side strake were made from ABS Grade A Steel.

2. Average Charpy impact energy value at 0°C for the bilge strake materials was 25J. The transition temperature was determined to be about 15°C which was higher than the service temperature. The scatter of the values at each test temperature was high, particularly at temperatures above 0°C.

3. Dynamic tear values for the bilge strake were low. The transition temperature was quite high, about 30°C.

4. The Dynamic Tear and Charpy Impact values were not adequate to provide protection against brittle fracture at the service temperature.

5. The critical crack depth for brittle fracture initiation calculated from COD results was about 7 mm which is in resonable agreement of the actual depth of 3 to 5 mm.

6. The energy absorbing capacity of the butt welds were not adequate to arrest or divert the cracks.

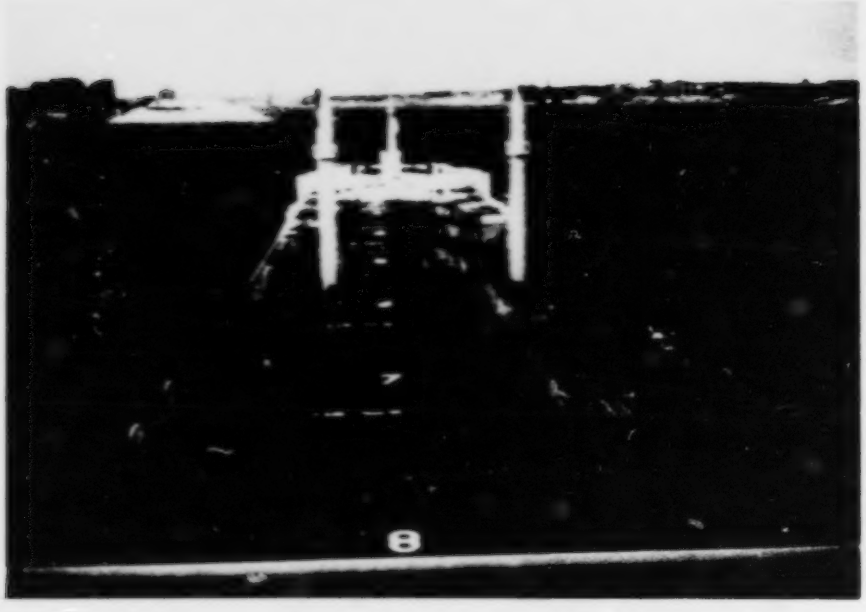
The sequences of events that led to this catastrophic failure are as follows:

1. Two fatigue cracks originated on both sides of the ship at the toe of the fillet welds situated near the tip of the stiffeners. The points of the crack origins were located in the fillet weld or near the fusion line on the shell plate side. The cause of the fatigue crack origin was a combined effect of (i) poor fillet weld, (ii) stress concentration, and (iii) the crucial cyclic service loading at the tip of the stiffener.

2. Once the fatigue cracks had penetrated to a depth of approximately 3 to 5 mm inside the bilge strake, the mode of cracking changed to brittle manner. The brittle crack was caused by (i) crucial loading, (ii) stress concentration at the extensive origin of fatigue crack, and (iii) low energy absorbing capacity of the shell plate material at the temperature concerned.

3. The brittle crack progressed to great lengths, (over 13 feet), through butt welds (manual and submerged arc) because the energy absorbing capacity of the butt welds were inadequate.

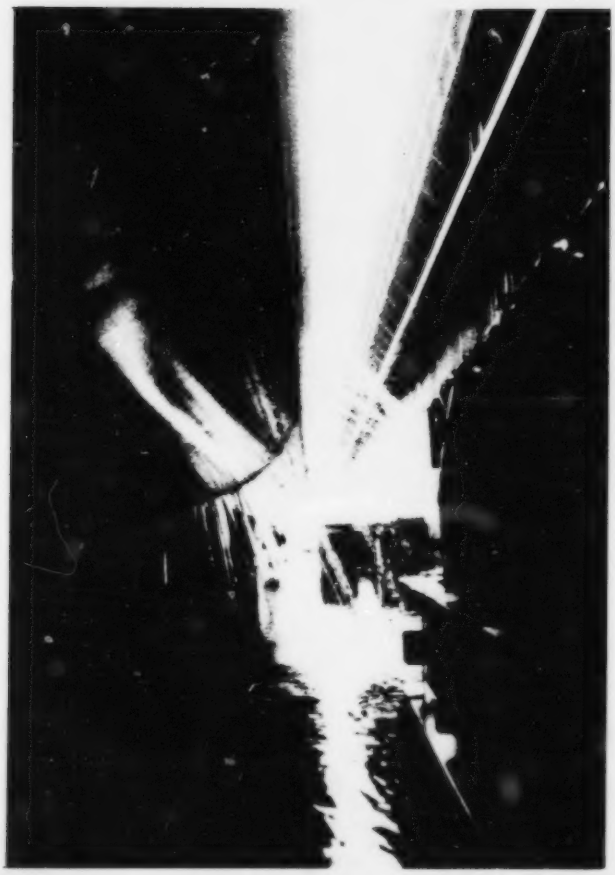
"DODSLAND"



O.B.O. "DODSLAND" at Halifax, N.E.

O.B.O. "DODSLAND" à Halifax (N.-É.).

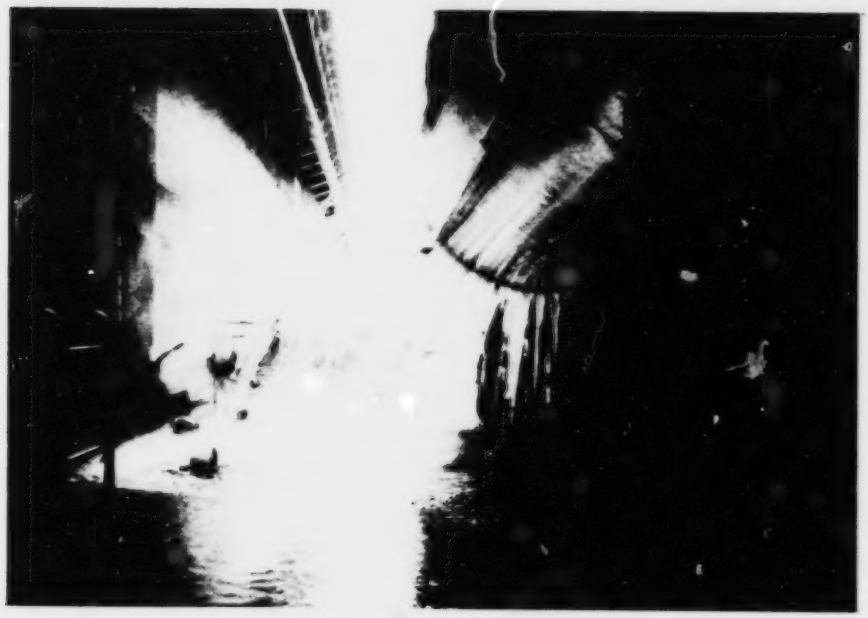
"DODSLAND"

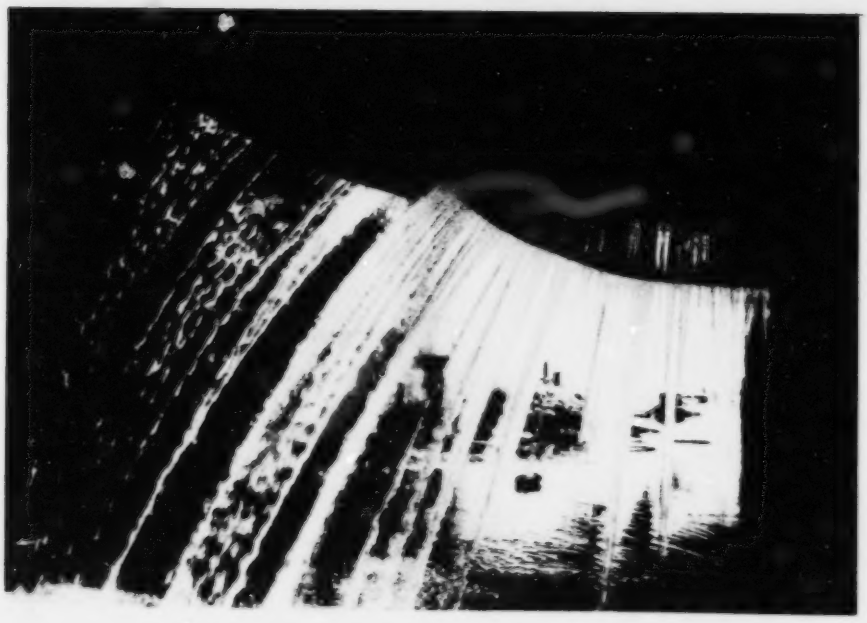


Water escaping from No. 3 port water-ballast tank after dry-docking.

Eau sortant du ballast bâbord n° 3 suite au bassin de radoub.

"DODSLAND"

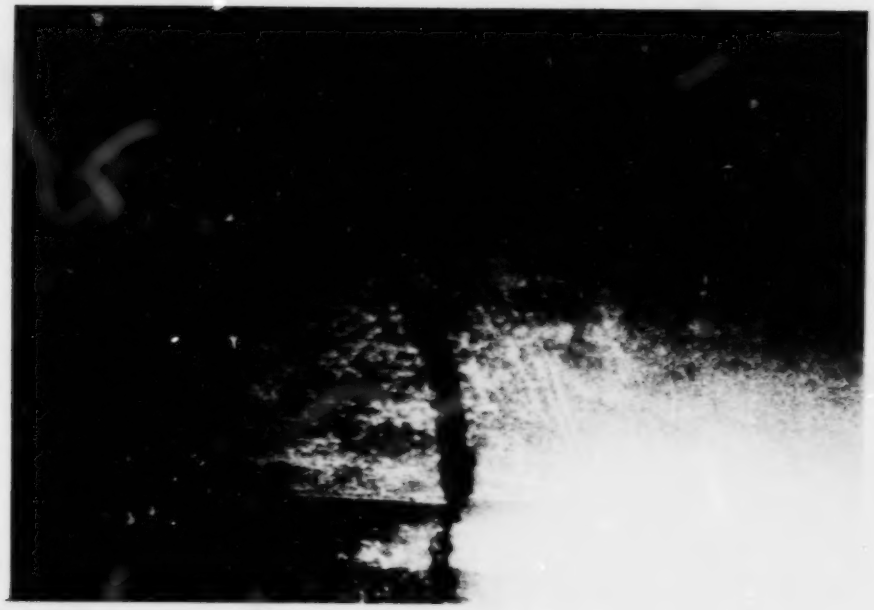


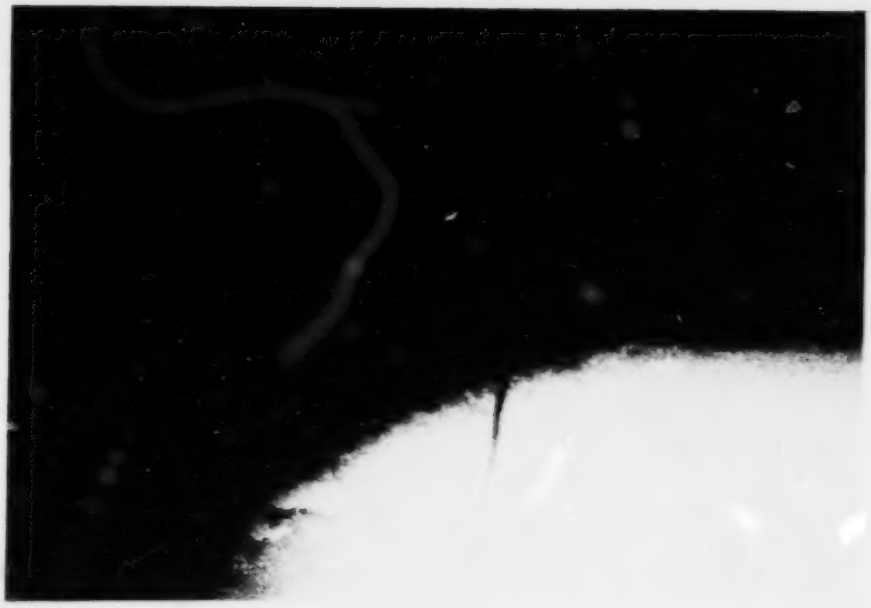


Water escaping from cracked No. 4 starboard water-ballast tank after dry-docking.

Eau sortant du ballast tribord n° 4 fendillé suite au bassin de radoub.

"DODSLAND"





Sub-sea photographs of cracks in hull.

Photographies sous-marines des criques dans la coque.